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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H01H 35/14

A1

(11) International Publication Number: WO 90/10302

(43) International Publication Date: 7 September 1990 (07.09.90)

(21) International Application Number: PCT/US90/01017

(22) International Filing Date: 22 February 1990 (22.02.90)

(30) Priority data:
314,603 23 February 1989 (23.02.89) US

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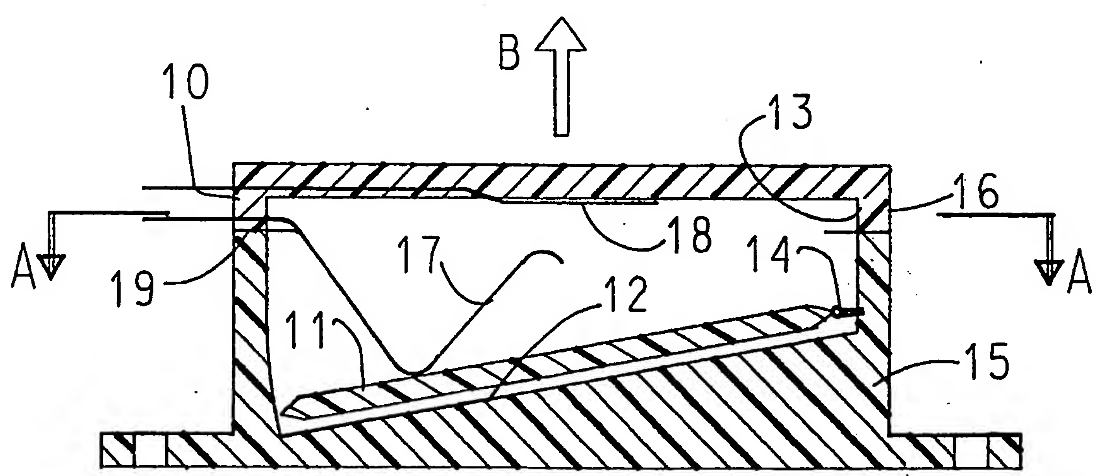
(81) Designated States: AT (European patent), BE (European patent), CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent).

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: IMPROVED AUTOMOBILE CRASH SENSORS FOR USE WITH PASSIVE RESTRAINTS



(57) Abstract

This invention includes crash sensors designed to be used for frontal and side impact sensing and the strategies of using these sensors. It is analyzed and shown that velocity sensing or damped sensors are desirable. Inertially damped sensors, with a damping force proportional to the square of velocity, is preferred for some applications. In other cases a viscous damped sensor is appropriate and in a few cases an undamped spring mass sensor will suffice. Such sensors can be made of plastic and in the shape of short housings. A preferred embodiment of this invention utilizes a swinging mass hinged to a housing (14, 15, 16) as the sensing mass. Different geometries of the mass and the housing are disclosed and used to improve the performance of such sensors. These flapper mass sensors are useful for sensing frontal and side impact both as primary sensors and as single or dual contact arming sensors. A method of manufacturing these sensors is also disclosed, in which the contacts (17, 18) are treated to become adhesive to plastic and then molded with the remaining plastic parts (15, 16) of the sensors. The plastic parts are then welded to form a hermetically-sealed interior of the sensor.

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IMPROVED AUTOMOBILE CRASH SENSORS FOR USE WITH PASSIVE RESTRAINTS

BACKGROUND OF THE INVENTION

Air bag passive restraint systems for protecting automobile and truck occupants in frontal collisions are beginning to be adopted by most of the world's automobile manufacturers. It has been estimated that by the mid-1990's all new cars and trucks manufactured will have air bag passive restraint systems. These air bag systems are designed to protect occupants in frontal impacts. Many people are additionally killed or seriously injured in side impacts, which typically involves one car running into the side of a second vehicle.

Many types of crash sensors have been proposed and several different technologies are now in use for determining if a crash is severe enough to require the deployment of a passive restraint system such as an air bag or seatbelt tensioner. Three types of sensors, in particular have been widely used to sense and initiate deployment of an air bag passive restraint system. These sensors include an air damped ball-in-tube sensor such as disclosed in Breed US patents 3974350, 4198864, 4284863, 4329549 and 4573706, a spring mass sensor such as disclosed in Bell US patents 4116132, 4167276 and an electronic sensor such as is part of the Mercedes air bag system. In addition, a crush sensing switch has been proposed which discriminates between air bag desired crashes and those where an air bag is not needed based on the crush of the vehicle as disclosed in Breed US patent __________. The subject of this invention is a new sensor which has some advantages over the prior art for some applications.

The choice of the sensor technology to be used on a given vehicle depends on where the sensor is mounted. When a car is crashing only certain portions of the vehicle are crushing at the time that the sensors must trigger to initiate timely restraint deployment. A car, therefore, can be divided into two zones: the crush zone, usually about the first 12 inches from the point of impact for frontal impacts and less for side impacts, which has changed its velocity substantially relative to the remainder of the vehicle at the time sensor triggering is required and the non-crush zone which is still travelling at close to the pre-crash velocity. To sense a crash properly in the crush zone the sensors must function as a velocity change indicator; that is, the sensor must trigger at approximately

a constant velocity change regardless of the shape or duration of the crash pulse. An exception to this rule is for very short pulse durations in side impacts for vehicles with weak door structures, where the velocity change required to trigger the sensor should increase as the pulse duration decreases as explained below. This invention is concerned with frontal crush zone, passenger compartment and side impact sensors, and ones that trigger on a constant velocity change for some implementations and where the velocity change function is tailorable for other implementations.

One application of this invention is for sensing side impacts. Approximately, one quarter of all injury-producing accidents in 1981 for example were side impacts in which the direction of the force was determined to be within 45 degrees of the lateral axis of the vehicle. According to the National Highway Safety Council of the National Highway Traffic Safety Administration, 22% of all fatalities were caused by interior side surfaces of the vehicle as compared to 68% of fatalities caused by frontal impacts that includes the steering wheel, windshield frame, instrument panel, and windshield. Since air bags are well on their way to alleviating injuries from frontal impacts, it is important now to focus on the next largest killer, side impacts.

In frontal impacts, the crush zone of the vehicle changes velocity early in the crash and sensors located typically within 12 inches of the front of the vehicle can, in most cases, sense the crash and initiate the inflation of the air bag long before the occupant has begun to move relative to the passenger compartment. Also, for most cases, there is little intrusion in the passenger compartment and thus the entire space between the occupant and the instrument panel or the steering wheel is available to cushion the occupant. In contrast, in side impacts there is almost always significant intrusion into the vehicle and the motion of the occupant relative to the vehicle interior begins immediately after impact. In addition, there is far less space for a restraint system and thus the injury-reducing potential of an air bag even if it were deployed in time, is substantially less for side impacts than for frontal impacts. For frontal impacts, air bags are designed to cushion a 50 percentile male in a vehicle travelling at 30 MPH into a barrier. It is unlikely similar protection for an absolute velocity change of the passenger could be achieved in side impacts, for the reasons listed above, without major modifications to vehicle side structures. Nevertheless, a significant percentage of side impacts occur at velocities low enough where an air bag could be of significant help in mitigating injuries.

To design a crash sensor for side impacts, the side-intrusion characteristics of a vehicle and the behavior of various parts of a vehicle during a side impact must be studied and fully understood. In a technical paper by V. Castelli and D. Breed, "Trends in Sensing Side Impacts," (SAE 890603) presented at the 1989 SAE Congress and Exposition in Detroit, the side intrusion problems and general vehicle response characteristics are discussed. In this paper, it is assumed that the marginal condition for an occupant to be critically injured occurs when the occupant impacts the side door panel at a critical speed "V-cr". A relative velocity of 10 to 12 miles per hour has typically been considered a reasonable threshold. Based on this criterion, the desired response curve of a side impact crash sensor can be determined by the impact conditions, such as vehicle-to-vehicle, vehicle-to-pole, or truck-to-vehicle accidents. The following discussion, includes a brief summary of the aforementioned paper. For additional details, please refer to the paper.

The behavior of a struck vehicle depends on the striking object. Since most of the side impact accidents involve one vehicle impacting a second vehicle, consideration of this type of car-to-car crash is essential for the design of crash sensors. Define the struck vehicle as the "target" vehicle, and the striking vehicle as the "bullet" vehicle. For the discussion of side intrusion, consider the target vehicle comprising two parts: the side door beam and outer panel, and the passenger compartment. Once the side door is hit by the bullet vehicle, the door beam and outer panel deforms significantly while the passenger compartment only gains a relatively small velocity change in the early stage of a crash. The side intrusion or crush increases continuously after the early penetration until the entire car reaches a common final velocity later in a crash. The responses of the target and bullet vehicles are functions of the impact angle and location, the impact speed, and the stiffness and weights of the vehicles.

The velocity of the side door panel increases immediately after the impact to a maximum velocity comparable to the velocity of the bullet vehicle, V1. This rapid rise in velocity can happen within five to ten milliseconds. The passenger compartment experiences a relatively small velocity change during this stage of the crash. The difference in velocity between the side door and the passenger compartment manifests itself in the crush of the vehicle. As the side structure stiffens in the deep post-buckling range, the resistance force increases and starts to decelerate the side door panel until finally the side panel and the passenger compartment reach a common velocity, V2. This final velocity is

estimated to be the momentum velocity, which is the original momentum of the bullet vehicle divided by the total masses of the bullet and target vehicles, assuming that the friction between the road surface and the vehicles is negligible and a perfectly plastic collision occurs. For two vehicles of the same mass and a 90° impact of the moving bullet into a stationary target, the final velocity, V2, will be approximately equal to one half of V1.

Another critical parameter in the design of side impact sensor is the time when the occupant is hit by the side door inner panel, designated as t-hit. The deciding factors that influence t-hit are the stiffness of the vehicles, the impact condition, and the distance between the occupant and the side panel. In most of the side impact cases, t-hit occurs before the side door panel reaches the final velocity, V2. A crash sensor must trigger ahead of t-hit to allow the protective apparatus to deploy at an earlier time, defined as t-trigger. The gap between t-hit and t-trigger is the period needed for the inflatable system to deploy.

The velocity, at which the side door hits the occupant, is defined as V-hit. If the two vehicles are of equal weight in the 90° impact described above, then the peak of velocity change of the side door panel can be as high as two times V-hit. For example, if V-hit is equal to 10 MPH, then the side panel of the target vehicle can experience a velocity rise up to about 20 MPH before it decelerates and finally reaches the final speed. In the marginally critical crashes, V-hit is equal to V-cr. This observation reveals that a crash sensor located at center points in the side door must require a velocity change higher than V-cr in an impulsive pulse, such as pulses in the range of 1-5 ms, to trigger. Otherwise, if a crash sensor is responsive to an impulsive pulse with a velocity change of V-cr, then in many cases when the side door panel experiences a rapid velocity change of V-cr but finally a drop to one half of V-cr for equal mass vehicles, there will be many undesired initiations of the protection apparatus.

The above discussion on the velocity change, to which a crash sensor must respond, is based on the assumption that a velocity-type sensor is placed on the side door beam. A velocity-type sensor is a sensor, which integrates a crash pulse and triggers when the velocity change exceeds a threshold value. Since a side impact crash sensor must not falsely trigger due to hammer blows or light pounding on the side door, which can cause significant local deformations on the side door, side door deformation can not be used as

the only criterion for detecting the severity of a side impact accident. A side impact displacement type sensor which responds to the crush of the side door panel, therefore, could cause frequent inadvertent sensor triggering. A side impact sensor must also trigger for other side crashes when the side door is not directly hit but the impact is severe enough so that the occupant needs the protection of an inflatable system. A displacement-type sensor in these cases will not trigger until the side crush of the vehicle progresses to the location of the sensor. This will result in late triggering or no triggering of the sensor and no protection for the occupant. On the other hand, a velocity-type sensor will simply respond to the velocity change sensed in a crash, thus it can be adjusted to a desired sensitivity to predictably detect the occurrence of a side impact even though the side door is not hit directly. Based on the above observations, the velocity type sensor is appropriate for side impact inflatable systems. To ensure the effectiveness of sensing, it is reasonable that more than one sensor be used for side impact sensing, for example, one would be located just before A-pillar, one just after B-pillar, and one at the center of the side door. By implementing such a sensing system, it can be assured that at least one sensor will trigger for almost all side crashes, in which the protection apparatus is needed.

Even though spring-mass inertial sensors also respond to a specified range of velocity changes, the sensitivity of these sensors increases as the pulse duration decreases. This means that these sensors will trigger with a smaller velocity change for pulses of shorter duration than longer duration. This trend contradicts the conditions of side impact sensing. On the other hand, viscously damped sensors, such as conventional ball-in-tube sensors, (as disclosed in US patents 3,974,350, 4,198,864, 4,284,863 and 4,329,549 all to D. Breed) respond to the same velocity change regardless of pulse duration. These sensors also do not meet the requirements of side impact sensors, which requires greater insensitivity for short, impulsive velocity changes. In inertially damped sensors, the motion of the sensing mass is opposed by a nonlinear damping force, such as a resisting force depending on the second power of the velocity induced by fluid flow through a restrictor such as an orifice. These sensors are naturally more sensitive to long pulses than to short pulses, but the sensitivity to very long pulses can be compensated by a high bias force. The ability to tailor the characteristics of these sensors in the range of pulses 5 to 50 ms makes them most appropriate for side impact sensing.

A crash sensor for sensing side impacts must be placed on the side door structure to be effective. This location is essential since it is sensing the velocity change of the portion of the vehicle which will eventually strike the occupant, and therefore serves as a good predictor of V-cr. If this sensor is placed on the door beam just inside the door outer panel, it will respond very quickly to the impact. If the sensor were placed at some other location in the vehicle, it would necessarily respond more slowly to a side impact into the door. Any crash sensor, to function properly, must be designed to operate either in the crush zone or out of the crush zone. Since there is insufficient signal anywhere else in the vehicle for side impacts, they can only be sensed in time with crush zone sensors. This sensor, therefore, must be in the appropriate crush zone in order to sense the crash in time. If the side door is not hit directly, the pulse propagated to the side door is delayed and stretched in its duration, as compared to the pulse generated in a direct side door impact. Therefore, to be effective, a crash sensor must be more sensitive to these longer or stretched pulses.

In another extreme case, such as hitting a soft cushion, the whole target vehicle may be subjected to a side velocity change while there is no penetration or deformation to the side door, and the occupant will move toward the side door and eventually hit the inside panel. Suppose V-cr is equal to 10 MPH and the gap between the occupant and the inside door panel is typically about 5 inches, then t-hit is approximately equal to 57 milliseconds assuming that the occupant travels with an average of 5 MPH from a zero initial velocity to a final 10 MPH speed. Notice that the side door panel and the passenger compartment in this case experience the same pulse. This indicates that at t-trigger, which is ahead of t-hit by a period needed for deployment, a sensor located on the side panel must respond to a velocity lower than V-cr. Even though these conditions are very rarely encountered, they can provide a guideline for the sensor design for pulses in the range of 30 to 45 milliseconds. For example, if a pulse of 50 milliseconds duration with a velocity change of 10 MPH is considered a marginal pulse, then the sensor will need to respond predictably to a velocity change of 6 to 8 MPH in the range of 30 to 40 milliseconds.

It may be desirable for a side impact sensing system to include safing (arming) sensors in addition to the discriminating sensors described above. In frontal impacts, velocity-type low-bias sensors located in the passenger compartment are used for safing purposes. In side impact crashes, however, the crash pulse in the passenger compartment does not

provide enough information at the time when the crush zone sensor is required to trigger. Therefore, it is difficult to use a passenger-compartment safing sensor for side impact sensing system. Safing sensors for side impact application could be crush sensing switches. These safing sensors should be placed in proximity to the velocity sensing sensors, and should have long contact dwells. A combination of a velocity sensing sensor and a crush sensor significantly reduces the probability of an inadvertent deployment by imposing a requirement that two environmental stimuli (velocity change and physical displacement) are required to initiate air bag deployment.

Air damped ball-in-tube crash sensors are inherently velocity change indicators and are the only sensors which have found widespread use for mounting in the crush zone. Spring mass sensors inherently trigger at smaller velocity changes for high deceleration levels and high velocity changes for low deceleration levels and therefore have only found widespread applicability in the non-crush zone locations of the car. Electronic sensors could be designed to function in either manner and thus could be placed either in the crush zone or in the non-crush zone. Although, the preferred implementation of this invention uses air damping, other implementations are undamped spring mass and electronic sensors.

Each of these sensors has significant limitations. If spring mass sensors are placed in the crush zone they will either trigger on very short duration low velocity change crush pulses where a restraint system is not needed or they will not trigger on longer duration pulses where a restraint is needed, depending on the particular sensor design and particular mounting location. In addition, since the motion of the mass in the spring mass system is undamped, it has been very difficult to get reliable contact closure on vigorous crash pulses where the mass bounces back and forth many times. To solve this contact problem, spring mass sensors are frequently placed slightly out of the crush zone for frontal barrier impacts. In this case, however, they sometimes become in the crush zone, for example in angle car to car impacts, and are prone to both triggering when a restraint is not desired and to the contact problems discussed above.

Electronic crash sensors have so far only been used in protected passenger compartment non-crush zone locations. Most electronic sensors have environmental limitations which are exceeded by crush zone locations which are frequently near the engine or radiator. Newer electronic technologies, however, have overcome these environmental limitations

and consideration can now be given to crush zone mounted electronic sensors.

The ball-in-tube sensor now in common use, triggers properly only when responding to longitudinal decelerations. When cross axis accelerations in the vertical and lateral directions are present, the ball can begin whirling or orbiting around inside the cylinder resulting in a significant change in the response of the sensor.

The ball-in-tube sensor depends upon the viscous flow of air between the ball and the tube to determine the characteristics of the sensor. The viscosity of air is a function of temperature and, although materials are selected for the ball and the tube to compensate for the viscosity change, this compensation is not complete and thus the characteristics of the ball-in-tube sensor will inherently vary with temperature. Certain implementations of this invention use viscous air flow and have the same limitations.

In addition, the biasing force which is used to hold the ball at its home position when a vehicle is not in a crash is sometimes provided by a ceramic magnet for the ball-in-tube crush zone sensor. This biasing force has a significant effect on the threshold triggering level for long duration pulses such as impacts into snow banks or crash attenuators which frequently surround dangerous objects along the highways. Due to the temperature effects on the magnet, this biasing force changes by about 40% over the desired temperature operating range of the occupant restraint system. Most implementations of the present invention use a spring for the bias thus eliminating this problem.

To function properly, a crush zone sensor of any design must be in the crush zone. Any crush zone sensor which is based on a mass sensing deceleration has a potential of triggering very late if it is not in the crush zone for a particular crash. This is particularly a problem with ball-in-tube sensors which have a very low bias. One example of this involved a stiff vehicle in a low speed barrier impact where the sensor was not sufficiently forward in the car and thus not in the crush zone. The sensor triggered when the entire velocity change of the car reached 10 MPH at which time the occupant was leaning against the air bag. An occupant who is severely out of position and close to the air bag when it deploys can be seriously injured by the deploying air bag. It is therefore important that at least one sensor be in the crush zone for all air bag desired crashes and that all crush zone sensors have sufficient bias to prevent late firing for low velocity long duration pulses. Sensors designed according to the teachings of this

invention, generally have a high enough bias that late triggering is not a problem

The ball-in-tube sensor is both expensive and subject to wide manufacturing tolerances. This is partially due to the small clearance which exists between the ball and tube. Since this clearance acts as the restrictor to fluid flow, it determines the calibration of the sensor. It therefore must be very carefully controlled. The tolerance on this clearance is typically on the order of .000050 inches which requires expensive machining and gaging manufacturing processes. Because of the difficulty in maintaining these tolerances and in particular the tolerance on the roundness of the cylinder, sensors exhibit a manufacturing calibration range of more than 20%!

All crush zone sensors are caused to trigger by being impacted by crushed material moving rearward as the vehicle crushes progressively during a crash. The geometry of this crushed material can vary from vehicle to vehicle and from crash to crash. If a sensor has a shape which causes it to project outward from its support in a cantilever fashion, it is prone to be rotated as it is impacted by the crushed material. In some cases, this rotation can be so severe as to prevent the sensor from triggering since the sensor is no longer pointed forward. A study of crushed vehicles form real life crashes has shown that rotation of the sensor mounting locations is frequently severe. If instead, the sensor has a flat shape with the thickness in the sensing direction small compared with the width and height of the sensor, the local shape of the crushed material impacting the sensor will have a smaller effect, the sensor will have a better support against rotation and the sensor will tend to align itself with the direction of force thus increasing the probability of properly sensing the crash.

One advantage of using inertial gas flow in a sensor is that the gas flow rate is not viscosity dependent. Since gas viscosity is sensitive to temperature variations, the performance of sensors utilizing viscous type of gas flow is significantly influenced by temperature changes. In inertially-damped sensors, the gas flow rate is a function of the pressure difference across the orifice and gas density only. As long as the gas density inside a sensor is kept constant, the behavior of the sensor is much less sensitive to temperature variations than viscously-damped sensors. In order to maintain a constant gas density inside the sensor, the interior of a sensor must be isolated or "hermetically" sealed from the ambient environment. The construction of this invention adapts a design that allows the manufacture of hermetically-sealed crash sensors. A "hermetically-

sealed" sensor is defined here as a sensor, which has no openings to the atmosphere and only allows a negligible amount of gas to enter into or escape from its interior over a considerable period. For example, if a sensor is made of plastic and sealed from the atmosphere, the only leakage that can occur is gas diffusion through the plastic material or along the seams or metal to plastic joints.

The configuration of some of the sensors disclosed herein consists of a rectangular flapper and a rectangular housing. A flapper, which is the sensing mass for sensing the acceleration of the crash, is a planer member having a thickness in the sensing direction which is much less than its width or height and is arranged to rotate relative to the housing. The flapper is coupled with the housing by a thin hinge on the edge of the flapper, by a knife edge support or other means. The axis of the housing is parallel to or aligned with the desired crash detecting direction. For example, if the sensor is to be used for frontal impact sensing, the sensor should be installed to have the axis of the housing approximately parallel to the front-rear direction of the vehicle. The flapper is arranged to rotate along an axis perpendicular to the axis of the housing.

The parts of the sensor of a preferred configuration of this invention can be manufactured by the plastic injection molding processes, in which the flapper, the hinge, and the housing are formed in a single piece. If the hinge in made form the same plastic as used for the flapper and the housing, then they can be formed in a single molding process. On the other hand, if the hinge is made from another material, such as metal or a different plastic, it can be formed into its shape first and then insert molded with the plastic parts. The contacts comprising the switching circuit for the sensor are also to be insert molded into the housing. To ensure that the sensor is hermetically sealed, the metallic parts can be first coated by a bonding material which adheres to both the contacts and the plastic. It is known that the contacts and the plastic have different thermal expansion coefficients and thus, if they are not treated, they could separate when the temperature changes and result in leaks. One coating material which is resilient and adhesive and prevents the separation of the metal and plastic materials within the normal crash sensor operating temperature range, usually specified at -40 F to 250 F, is disclosed in patent #3,522,575 of Watson et al and is new to the field of crash sensors. The coating material mentioned in the Watson patent is a phenolic resin with 6 percent content of polyvinyl chloride. This manufacturing method not only eliminates the need of additional assembly steps, but also provides the hermetical sealing for the sensors.

The sealing of the sensor from the ambient environment is important to keep the gas density constant inside the sensor which renders the sensor insensitive to temperature changes. Furthermore, it can also isolate the interior of the sensor from dust and moisture which could interfere with the motion of the flapper or the flow of the gas through the orifice. With this new technique, therefore, the sensor can be assured for a long and reliable life which is very important for automotive safety system components.

SUMMARY OF THE INVENTION

To satisfy the various requirements for a frontal impact crush zone sensor having an inertial mass, it is concluded that damping of the motion of the mass is desirable; if the clearance between the mass and housing is used as the restrictor, it should be made as large as possible to permit the largest tolerances on the mass and housing dimensions; inertial flow damping is preferable since it is less effected by the clearance and temperature; and the sensor should have a flat shape to minimize the chance of sensor rotation from impacts with crushed material. It is also disclosed that at least two sensors, one on either side is most desirable for frontal impact sensing to maximize the chance that one will be in the crush zone during the crash. Some large cars may need an additional center mounted sensor. Finally, the sensor design must minimize environmental effects such as temperature and cross axis vibration.

To satisfy the various requirements for a side impact sensor, it is concluded that a sensor having an inertial mass is required; a damped sensor is desired; and, an inertially damped sensor is most adaptable to properly sensing side crashes. It is also disclosed that a combination of three sensors, one just before the A-pillar, one just after the B-pillar, and one at the center in the side door, is most desirable for side impact sensing. Some small cars may need only two discriminating sensors per side. A crush sensitive safing sensor in series with and located proximate to the velocity change sensor is also desirable to minimize the chance of inadvertent air bag deployment.

It is a principal object of this invention to provide a crash sensor having an inertial mass for use with a frontal impact protection apparatus which avoids the limitations of the prior art.

It is another object of this invention to provide a sensing device which minimizes the risk of inadvertent actuation.

It is an additional object of this invention to provide an easily manufacturable sensor, with wide dimensional tolerances and which is inexpensive to make.

It is another object of this invention to provide a inertial flow sealed crash sensor, which maintains a constant gas density and thus is minimally affected by temperature changes.

It is a further object of this invention to provide a crash sensor, which is insensitive to the variations of ambient temperature.

It is a further object of this invention to provide a sensor with a flat shape which is resistant to rotation during the sensing portion of a crash.

It is yet another object of this invention to provide a sensor with is not significantly effected by cross axis accelerations.

It is another object of this invention to provide a sensor which can be easily manufactured to tight calibration tolerances.

Yet another object of this invention to provide a sensor which is testable.

It is a principal object of this invention to provide a crash sensor having an inertial mass for use with a side impact protection apparatus.

It is a further object of this invention to provide for at least two discriminating sensors per vehicle side.

It is the primary objective of this invention to provide a new and reliable design for crash sensors for mounting in the passenger compartment.

It is also the objective of this invention to manufacture the major parts of the crash sensor by a plastic molding process.

It is an additional objective of this invention to have the contacts of a sensor insert molded with the body of the sensor in a single molding process.

It is a further objective of this invention to simplify the manufacturing process to produce crash sensors in large quantities.

It is an additional objective of this invention to provide hermetic sealing to crash sensors by applying a metal-plastic bonding surface treatment to the contacts.

It is another object of this invention to provide a damped crash sensor based on inertial gas flow.

Other objects and advantages of this invention will become apparent from the disclosure which follows.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a transverse cross sectional view of a square plastic frontal or side impact crush zone sensor containing an integral molded hinge.

FIG. 2 is a cross sectional view taken along lines A-A of FIG. 1.

FIG. 3 shows a frontal view of a vehicle, illustrating the preferred mounting locations of frontal crush zone sensors.

FIG. 4 is an elevated view of the sensor and preferred mounting structure to minimize the chance that the sensor will be rotated during a crash.

FIG. 5 is an elevated view of the standard ball-in-tube sensor showing its mounting structure.

FIG. 6 is a transverse cross sectional view of a simple spring-mass sensor with a large cross section dimension and a relatively small thickness.

FIG. 7 is a transverse cross sectional view of a viscously damped disk sensor with a

relatively large diameter and a short travel.

FIG. 8 is a transverse cross sectional view of another preferred embodiment of a testable frontal crush zone sensor having a rectangular metal housing.

FIG. 9 is a transverse cross sectional view of the testable frontal impact sensor depicted in FIG. 8, viewed along B-B.

FIG. 10 is a typical response curve of a preferred embodiment of the invention using inertial gas flow.

FIG. 11 is a transverse cross sectional conceptional view of an electronic frontal impact crush zone crash sensor.

FIG. 12 is an illustration of a side impact protection system, shown in different stages of deployment during a crash.

FIG. 13 shows a side view of a vehicle, illustrating the preferred mounting locations of side impact sensors.

FIG. 14 is a transverse cross sectional view of a crush sensing safing sensor.

FIG. 15 is a cross section view of a square plastic inertially damped arming or passenger compartment discriminating sensor containing an integral molded hinge.

FIG. 16 is a cross section view taken along lines A-A of FIG. 15.

FIG. 17 is a magnetically biased viscously damped disk sensor with a relatively large diameter and a short travel.

FIG. 18 depicts an embodiment of a sensor of this invention with a semi-circular disk geometry.

FIG. 19 illustrates the side cross-sectional view of the sensor in FIG. 18.

FIG. 20 is a cross-sectional view of the sensor in FIG. 18.

FIG. 21 is another cross-sectional view of the sensor in FIG. 18.

FIG. 22 is another embodiment of a sensor of this invention with a rectangular disk geometry.

FIG. 23 illustrates the side cross-sectional view of the sensor in FIG. 22.

FIG. 24 is a cross-sectional view of the sensor in FIG. 22.

FIG. 25 illustrates a procedure of manufacturing a crash sensor.

DETAILED DESCRIPTIONS OF PREFERRED EMBODIMENTS

One preferred embodiment of this invention is manufactured as a thin square or rectangular housing with a width slightly larger then 2 inches, and a thickness of .5 to .75 inch. FIG. 1 is a cross sectional view of such a frontal crush zone sensor 10. A member or flapper 11, initially resting on an inclined surface 12, is hinged to the inside surface of the housing 13 by a plastic or metal hinge 14. The housing comprises a left casing 15 and a right casing 16. A first contact 17, attached to housing 13, biases the flapper 11 toward its initial position. A second contact 18 is also fixed to the housing 13. When installed on a vehicle for frontal impact sensing, the right side of the sensor faces forward in the direction of the arrow B.

When the sensor is subjected to a crash pulse of enough magnitude and duration, the flapper 11 moves toward contact 18. After a specified travel, the first contact 17 makes contact with 18 and closes an electrical circuit to initiate deployment of the protection apparatus associated with the sensing system. The first contact is flexible and allowed to deflect further beyond the triggering position. Therefore, the flapper can travel over and beyond the triggering position until it is stopped by the wall 19 of the housing. This over travel is necessary in order to provide a long contact duration or dwell. If the acceleration of the crash pulse drops below the bias level later in the crash, then the flapper moves back toward its initial position under the biasing force of contact 17.

Flapper 11 and the left housing casing 15 can be produced as a single plastic piece by injection molding. The flapper and the housing are attached by a plastic hinge formed in the manufacturing process or by a metal, plastic or other material hinge insert molded during the molding process. A candidate for the plastic material with well known hinge properties is polypropylene, which is strong and durable enough to provide a flexible bonding between the flapper and the housing. Since it is difficult to maintain tolerances in unreinforced polypropylene, other plastics would be more suitable for some applications.

The right side of the housing 16 is also to be made of plastic and formed by injection molding, while the contacts 17 and 18 are made of conductive metals and can be inserted into the plastic part in the molding process, thereby combined into a single piece to be assembled with the left side of the sensor. The assembly of the sensor is completed by

combining the two parts of the housing by heat sealing, ultrasonic sealing, through use of a compression sealing ring (not shown) or other suitable sealing method. With the appropriate metal-plastic adhesive coating on the metal pieces, the metal parts and the plastic can be bonded within the range of the operating temperature of a sensor. This manufacturing technique hermetically seals the sensor assuring that the gas density remains constant and prevents moisture and dust from entering the sensor.

A major difference between the preferred embodiment of the sensor disclosed in this invention and a typical ball-in-tube sensor is the damping effect provided by the gas flow. The gas flow in this embodiment of this invention is of the inertial type. Therefore, the resisting force caused by the pressure difference is proportional to the second power of the gas velocity. Viscous damping utilized in ball-in-tube sensors, on the other hand, is linearly proportional to the gas flow velocity. Inertial type damping is not dependent on the viscosity but instead on the mass flow of the gas and therefore is insensitive to temperature changes, assuming that the sensor is sealed and gas density is therefore kept constant.

The motion of the flapper is determined by the bias, the pressure force, and the inertial force caused by the crash pulse. The size of the flapper of the preferred embodiment can be in the range of 1 to 3 inches, which is much larger than the diameter of other known crash sensors. This large size has two significant advantages. First, the clearance between the flapper and the housing becomes large in comparison to conventional ball-in-tube sensors, for example. Thus the tolerance on this clearance is also sufficiently large as to permit the parts to be molded from plastic. Furthermore, if both parts are molded simultaneously in the same mold, this clearance can be held quite accurately. Also, for inertial flow, the resistance to gas flow is proportional to the first power of the clearance while for viscous flow, it is proportional to either the third power (for a cylindrical piston) or the 2.5 power (for a spherical piston). This further reduces the effect of manufacturing variations on the clearance and improves the accuracy of the sensor.

A computer program simulating the motion of the flapper inside the housing is used to analyze the sensor performance. One example of a sensor with rectangular disk as described in FIG. 18-21 has the following parameters:

mass (disk)	= 3 grams
disk height	= 1.5 inches
disk width	= 2.5 inches
clearance	= 0.010 inches
initial disk position	= -10 degrees (counter clockwise from vertical position)
triggering position	= -5 degrees (counter clockwise from vertical position)
disk travel limit	= +12 degrees (clockwise from vertical position)
initial bias	= 1.0 G's
average bias	= 8.0 G's

Simulation of the sensor is conducted using haversine pulses of different duration. The sensor with the above parameters is found to marginally trigger at:

PULSE DURATION (MS)	VELOCITY CHANGE (MPH)
10	11.4
15	9.7
20	9.2
25	9.1
30	9.3
35	9.5
40	9.8
45	10.4
50	10.8

Since this sensor has a marginal velocity change of 9-11 MPH in the range of 10-30 milliseconds, it is a candidate for a crush zone sensor since signals received in the crush zone usually possess a rapid velocity change within 10-30 milliseconds, and a velocity change of 10 MPH is commonly accepted as a threshold for critical injuries. Depending the crash responses of a vehicle and the mounting location of the sensor, the parameters of the sensor, such as clearance and bias, can be adjusted to fit the desired specifications.

Although not shown in the drawings, the sensors of this invention can contain a mechanism for adjusting the initial position of the flapper to compensate for the remaining tolerances. For all of the above reasons, a sensor which is considerably more accurate than currently available mechanical crash sensor, results. Furthermore, the large width and thin shape of the preferred sensors is well adapted for sensing frontal or side impacts in the crush zone since the tendency will be for the sensor to align itself such that the principle direction of force is parallel to the axis of the flapper. A small sensor, for example, might rotate so as to place its sensitive axis in a direction substantially different from the principle direction of force. Width herein refers to the maximum horizontal dimension of the sensor and height refers to the maximum vertical dimension of the sensor. Sensors for use in the crush zone for frontal or side impacts, generally are quite thin having a thickness which is less than one half of either the width or height.

This ability to make the sensor entirely from plastic (with the exception of the contacts) makes this sensor quite easy to manufacture and very inexpensive to produce.

To ensure that the sensor is hermetically sealed, the metallic parts can be first coated by a bonding material which adheres to both the contacts and the plastic. It is known that the contacts and the plastic have different thermal expansion coefficients and thus, if they are not treated, they could separate when the temperature changes and result in leaks. One coating material which is resilient and adhesive and prevents the separation of the metal and plastic materials within the normal crash sensor operating temperature range, usually specified at -40 F to 250 F, is disclosed in US patent #3,522,575 of Watson et al and is new to the field of crash sensors. The coating material mentioned in the Watson patent is a phenolic resin with 6 percent content of polyvinyl chloride. This manufacturing method not only eliminates the need of additional assembly steps, but also provides the hermetical sealing for the sensors.

An inertially-damped sensor is naturally more sensitive to long duration pulses since the gas velocity is less and the flow resistance is proportional to the second power of the gas velocity. For this reason the sensor sensitivity to velocity change for long pulses must be adjusted by the bias level. A computer program simulating the motion of the flapper is used to analyze and determine the appropriate dimensions and the bias level.

In an inertially damped sensor, the velocity change required to trigger the sensor depends

on the duration of the crash pulse. This sensor in general requires a larger velocity change to trigger for short duration pulses than for long duration pulses. However, this effect can be tailored by controlling the initial air volume behind the flapper. Since air is compressible, some motion of the mass is required before a pressure drop associated with a given level of acceleration is achieved. Thus the pressure behind the flapper drops, the gas expands and the initial motion of the flapper is substantially undamped. The magnitude of this effect depends on the amount of gas trapped behind the flapper.

The bias is used to adjust the sensitivity of the sensor to long duration pulses. A typical response curve is shown in FIG. 10 for an inertially damped sensor. The curve shows the marginal trigger/no-trigger response to a haversine acceleration input pulse having varying durations (horizontal axis) and varying velocity changes (vertical axis). The sensor will trigger for all pulses having a velocity change above the curve and not trigger for all velocity change pulse duration combinations lying below the curve. By adjusting the size of the clearance, the mass of the flapper, the initial air volume behind the flapper and the bias, the sensor response curve can thus be tailored to achieve a wide variety of response curves and thus matched to the requirements of a particular application.

The embodiment of the sensor shown in FIG. 1 would utilize a flapper with a width of 2 inches, a diametrical clearance of 0.02 inch and a flapper mass of 3 grams. The average bias provided by the contact spring would be between 8 and 10 G's. This configuration achieves a desired response curve for a sensor where the sensor will marginally trigger on a 10 mile per hour crash.

The thin pancake shape of the sensor of this invention lends itself to be easily mounted in the preferred locations for sensing frontal impacts. This usually requires mounting within twelve inches from the front of the vehicle. However, for some small stiff cars, the crush zone only extends rearward about five inches at the time that sensor triggering is required. As shown in FIG. 4, these locations include the right and left sides of the radiator, 31 and 33, or some other suitable location which is in the proper geometric relationship to the front of the car so as to guarantee that at least one sensor will always be in the crush zone for air bag desired crashes. For some large cars, an additional sensor located on the center of the radiator 32 might also be required to catch direct centered impacts into poles, for example. These three sensors are electrically wired in parallel such that if any of these sensors triggers, deployment of the protection

apparatus is initiated.

The thin pancake shape of the sensor of this invention also lends itself to be easily mounted in the preferred locations for sensing side impacts. These locations include in the center of the side door 332, plus in front of the A-pillar 331 and just behind the B pillar 333 as shown in FIG. 13. In each case, the sensor would be mounted just inside the sheet metal skin of the vehicle, and attached to a beam or support member. These three sensors are electrically wired in parallel. If any of these three sensors triggers in a side crash, then the protection apparatus is initiated.

FIG. 12 illustrates the deploying process of an air bag for side impact protection. The inflator 321 and the bag 322 are stored between the door outside panel 323 and the inner panel 324. In a side impact accident, the bumper of the bullet vehicle 325 penetrates the side door of the target vehicle. After a discriminating sensor 320, plus a safing sensor (if present) as described below trigger, the bag starts to deploy and fills the gap between the occupant 330 and the door by pushing and displacing the inside panel 324. In some designs the air bag merely fills the space between the occupant and the door, and does not attempt to cushion the impact of the occupant's head against the window. In other designs, the air bag is considerably larger and pushes the occupant away from the intruding door. In this latter configuration, a greater level of protection is achieved through accelerating the occupant away from the door before the door intrudes to impact the occupant.

Side impact sensing is a new field. The only prior art in the literature utilizes a crush sensing switch as a discriminating sensor to detect a side crash. As discussed above, such a sensor will lead to frequent inadvertent triggering due to local deformations. Therefore, a velocity sensing device is desirable, and inertially damped, velocity change sensors are the most suitable. Nevertheless, spring mass type sensors have the advantage of being simple and easier to implement.

A preferred mounting structure for frontal crush zone applications is shown in FIG. 4. In this case the sensor is mounted to the radiator with four support tabs 61. An offset impact to the sensor will cause these tabs to collapse displacing the sensor sideways but maintaining its forward orientation, as shown in FIG 4A. In contrast, a typical mounting method used for the conventional ball-in-tube sensor is shown in FIG. 5 and the result of

an off center impact between the crushed metal moving rearward during a crash and the sensor, shows, in FIG 5A, the sensor rotated away from the forward direction.

From the above discussion, a velocity sensing device is desirable, and inertially damped, velocity change sensors are the most suitable. Nevertheless, spring mass type sensors have the advantage of being simple and easier to implement, and if they are carefully placed in the crush zone at the proper distance form the front of the vehicle as taught in Breed US patent ________________, they will function properly in most cases. FIG. 6 is an example of a spring-mass sensor 40. It consists of a sensing mass 41, a biasing spring 42, and a pairs of contact 43 and 44. The sensing mass 41, mounted in disk 45, is held at an initial position by the biasing spring 42. In a crash, sensing mass 41 moves toward end 46 of the housing and closes contacts 43 and 44 if the crash pulse is of enough magnitude and duration.

Similarly, FIG. 7 depicts a viscously damped sensor 50 adapted to be used for frontal or side impact sensing. A disk 51 with arc edge 52 is arranged to move in a cylinder 53. A spring 54 provides the biasing force. Contacts 55 and 56 will close an electrical circuit if the disk moves to a specified position. Due to the tight clearance and the large area on the arc edge, the flow through the clearance when the disk is moving is of the viscous type. Such gas flow can provide a damping force linearly proportional to the velocity of the disk. The curved edges 52 of the disk permit it to rotate or roll about any contact point between it and the cylindrical housing 53. This design substantially eliminates the effects of sliding friction regardless of the direction of force. Since the disk is only a portion of a sphere, it is constrained from rotating about its transverse axes. This has the effect of substantially eliminating the adverse effects of cross axis accelerations which can cause the ball in conventional ball-in-tube sensors to rotate and whirl all of its principal inertial axes. The materials for the disk and cylinder must, of course, be chosen with different thermal expansion coefficients to compensate for the viscosity change of the gas with temperature as taught in the above referenced patents on ball-in-tube sensors.

FIG. 8 depicts an alternate preferred design of an inertial flow frontal or side impact crash sensor which is manufactured from metal and is testable. Some automobile manufacturers have a requirement that crash sensors be testable. At some time, usually during the start up sequence, an electronic circuit sends a signal to the sensor to close

and determines that the contacts did close. In this manner, the sensor is operated and tested that it is functional. The testable sensor 100 of FIG. 8 consists of a metal flapper 101 which is hinged using a knife edge hinge 102. The flapper 101 is held against knife edge 102 by a contact and support spring 103 which exerts both a horizontal force and a bias moment onto the flapper. During operation, flapper 101 is acted upon by inertial forces associated with the crash and begins rotating around pivot 102. A small motion of the flapper however, expands the gas behind it creating a pressure drop which resists the motion of the flapper. This pressure drop is gradually relieved by the inertial flow of the gas through the clearance 105 between flapper 101 and orifice plate 106. If the crash is of sufficient severity, flapper 101 rotates until contact 107 of contact spring 103 contacts contact 108 of contact spring 109 and completes the electrical circuit initiating deployment of the occupant protective apparatus. Once contact is made, the flapper 101 can continue to rotate for an additional amount sufficient to assure that the contact dwell is long enough to overlap with an arming sensor, if present, and provide enough current to ignite the squib which initiates the gas generator which, in turn, inflates the air bag.

Testing is achieved by applying a current, typically less than 2 amps, to the coil 110. When such a current is present, a magnetic circuit composed of the metal housing 111, pole 112, orifice plate 106 and flapper 101, leads the flux lines so as to create an attractive force between the pole 112 and the flapper 101 drawing the flapper into contact with the pole and causing contact 107 to contact contact 108 and complete the circuit.

FIG. 9 is a cross sectional view through the sensor of FIG. 8 along lines C-C.

FIG. 11 is a conceptional view of an electronic sensor assembly 201 built according to the teachings of this invention. This sensor contains a sensing mass 202 which moves relative to housing 203 is response to the acceleration of housing 203 which accompanies a frontal impact crash. The motion of sensing mass 202 can be sensed by a variety of technologies using, for example, optics, resistance change, capacitance change or magnetic reluctance change. Output from the sensing circuitry can be further processed to achieve a variety of sensor response characteristics as desired by the sensor designer.

FIG. 14 is one embodiment of a crush sensing switch to be used as the safing sensor as

part of a sensor system for side impacts. A deformable dome-shaped membrane 360 is supported by a cylindrical element 361, which is extended from a base 363. The membrane 360, preferably made of spring steel, is coupled with an insulating layer 364 and a conductive contact 365. A dome-shaped second contact 366 is insulated from the base 363 by element 367. Contacts 365 and 366 are connected through cylindrical element 361 by flexible leads 368 and 369. When installed on the side structure of a vehicle, membrane 360 is facing the outside of the vehicle. When a crush occurs, the membrane 360 is pushed and deformed downward and contacts 365 and 366 closes an electrical circuit. Other switch designs such as disclosed in US Patent ________________ of D. Breed could also be used as safing sensors in series with the discriminating sensors described herein.

If the technique of metal-plastic coating, as described above, is applied to crash sensors as suggested in this invention, the bonding between the conductor and the plastic of a sensor can be insured within the operating temperature range for crash sensors, which is usually specified at from -40 F to 250 F. Not only crash sensors, but also many other devices containing electrical conductors used on vehicles, will benefit from this application of bonding between conductors and plastics. Such bonding can be provided by a resilient coating material, such as the one disclosed in the patent of Watson et al.

A preferred embodiment of this invention is manufactured as a short housing with a width of 1 to 2 inches, and a thickness of 0.5 to 0.75 inch. FIG. 15 is a cross sectional view of such a passenger compartment discriminating sensor 410. An inertial mass flapper 411, initially resting on an inclined surface 412, is hinged to the inside surface of a housing 413 by a plastic hinge 414. The housing 413 is comprised of a left casing 415 and a right casing 416. A first contact 417, attached to housing 413, biases the flapper 411 toward its initial position. A second contact 418 is also fixed to the housing 413. When installed on a vehicle, the right side of the sensor faces the front of the vehicle in the direction of arrow B.

FIG. 16 is a cross section view of the sensor of FIG. 15 taken along lines A-A.

FIG. 7 depicts a viscously damped sensor 50 which can also be adapted to be used for passenger compartment sensing. Although a spring 54 is shown providing the biasing force, this bias could also be provided by a magnet as shown in FIG. 17. Contacts 155 and

156 will close an electrical circuit if the disk moves to a specified position. Due to the tight clearance and the large area on the arc edge, the flow through the clearance when the disk is moving is of viscous type. Such gas flow can provide a damping force linearly proportional to the velocity of the disk. Naturally, as for any viscously damped sensor, means must be provided to compensate for the change in the gas viscosity with temperature. Such means could employ the use of materials with different thermal expansion coefficients for the disk and housing.

FIG. 18 is a perspective view of another preferred embodiment of a crash sensor of this invention. Sensor 470 is installed on a vehicle with axis 471 parallel to the desired crash-detecting direction. Leads 472 and 473 are extensions of contacts inside the sensor. These leads are connected to an electrical circuit, which is used to initiate the operation of a protection apparatus associated with the sensor when the sensor is triggered by a crash pulse.

FIG. 19 is a cross-sectional view of the sensor shown in FIG. 18. The sensor comprises a disk 474 and a passage 475. Disk 474 is coupled with housing 475 by a hinge 476. Disk 474 initially rests on a surface 477 and is biased toward the initial position by a biasing spring 478. The bias spring also acts as a first contact. Another contact 479 is located on a second location inside the housing.

Another cross sectional view of the sensor, shown in FIG. 20, is taken from line A-A of FIG. 19 and clearly demonstrates the geometries of the semi-circular disk 474 and the semi-circular housing 475. Hinge 476 connects disk 474 to housing 475. The clearance 480 between the disk and the housing controls the damping effect on the motion of the disk.

FIG. 21 is another cross-sectional view of the sensor taken from the direction of line B-B shown in FIG. 19. This drawing shows the semi-cylindrical passage 475, the contacts 478 and 479, and the leads 472 and 473 extending from the contacts.

If a crash occurs, disk 474 moves toward contact 479. If the crash is of enough magnitude and duration, disk 474 pushes contact 478 toward contact 479 and closes a circuit. Contact 478 is flexible so that disk 474 is allowed to move further after the contacts are closed. This travel after contact is important for a sensor to maintain

contact after the sensor has triggered and to provide a long duration of contact. During the motion of the disk 474, gas flows around the disk through the clearance 480 and introduces a damping effect on the motion of the disk.

FIG. 22 is a perspective view of another embodiment of this invention. Sensor 490 comprises a rectangular disk 481 indicated by the dashed lines in FIG. 22. The curved surface 482 constitutes a portion of the passage inside the sensor.

FIG. 23 is a cross-sectional view of the sensor shown in FIG. 22. The disk 481 is coupled to the housing 483 by three hinges 484 along one edge of the disk instead of a continuous hinge as is the case of FIG. 20. In this case, the hinges are preferably made from metal and insert molded into the body and flapper. The gap 485 between the disk 481 and the housing 483 along the other three edges of the disk 481 is the orifice area which restricts the gas flow.

FIG. 24 is a side view of the sensor in FIG. 22. The interior of housing 483 is designed to match the shape of the disk. The inner surface 482 of housing 483 is curved. With this interior geometry, the orifice area can be kept constant throughout the travel range of disk 481. The uniform orifice feature provided by the geometry of sensor 490 will allow a maximum clearance to be used for the same total amount of damping.

The functions of contacts 486 and 487 are similar to those of contacts 478 and 479 described in FIG. 19. Naturally more than one pair of contacts could be used within one sensor. With the rectangular shape of the flapper, it is easier to allocate spaces for multiple sets of contacts. Dual contacts may be desirable for a safing sensor where separate switches for driver-side and passenger-side gas bag systems are sometimes desired.

The rectangular geometry of the disk of sensor 490 also provides a greater flexibility of choosing dimensional ratio of height to width, while the semi-circular disk has a fixed 1-to-2 ratio of height-to-width. Such flexibility allows the selection of dimensions to accommodate the sensor on desired locations on a vehicle.

An example using the rectangular disk geometry is investigated for simulating a safing sensor to be installed in the passenger compartment.

mass (disk)	= 3 grams
disk height	= 1.0 inches
disk width	= 1.0 inches
clearance	= 0.010 inches
initial disk position	= -10 degrees (counter clockwise from vertical position)
triggering position	= -4 degrees (counter clockwise from vertical position)
disk travel limit	= +12 degrees (clockwise from vertical position)
initial bias	= 0.5 G's
average bias	= 1.7 G's

If the simulation of the sensor is conducted with haversine pulses of different duration, the sensor with the above parameters is found to marginally trigger at:

PULSE DURATION (MS)	VELOCITY CHANGE
10	0.90
20	0.95
30	1.09
40	1.20
50	1.39

Since this sensor has a marginal velocity change of 0.9-1.4 MPH in the range of 10-50 milliseconds, it is a candidate for a safing sensor.

The above two embodiments of FIG. 18 and FIG. 22 illustrate the principle of this invention. Although the semi-circular and the rectangular geometries are demonstrated here, the invention is not restricted by these two shapes. As long as the interior of the housing is tailored to fit the shape of the disk, other geometries can be used to fully accomplish the purposes of this invention.

Although a damped sensor has been illustrated for use as an arming sensor, this damping may not be necessary for some applications where a slightly shorter contact duration can be tolerated. If the damping is not required, the clearance between the flapper and housing can be made much larger resulting in a pure spring mass sensor. Such a sensor

would be less expensive to manufacture.

In the preferred embodiments mentioned above, the hinge connecting the flapper and the housing can be constructed in several ways. If the same plastic material used for both the flapper and the housing is suitable for the hinge and the thickness of the hinge is manufacturable by the molding process, then the hinge, the flapper and the housing can be formed in the same process by the same plastic material. An alternate way is to form the hinge from a metal or a different higher melting plastic and insert the hinge into the plastic part in the molding process. In this case, the bending stiffness of the hinge could also be used for biasing. An example of producing such a sensor is illustrated in FIG. 25.

FIG. 25 (a) shows the contacts 201 and 202 as formed before insertion into the mold. FIG. 25 (b) shows the contacts molded into a single, extended piece 203 with the plastic parts 204, 205, 206, and 207 of the sensor. FIG. 25 (c) shows the sensor in its final shape with the parts 204 and 207 bent into their proper positions. The side surfaces 204 and 207 are fused or welded into the housing 205 to form an hermetically sealed sensor 200. Part 206 becomes the flapper, and conductor 201 serves as both a contact and a hinge. In this example, no additional bias spring is needed because conductor 201 works as a cantilever beam, providing the required biasing force.

A sharp edge 208 is formed on the upper interior of housing 205 as shown in FIG. 25, while the upper edge 209 of flapper 206 is smoothly profiled. Inertial gas flow is made possible by the sharp edge 208 although the surface 209 of flapper 206 has a cylindrical profile to mate with edge 208. The sides of flapper 206, on the other hand, are flat to mate with the corresponding portions of edge 208 always maintaining a constant clearance around the flapper 208. This option is necessary when a sharp edge of the flapper is difficult to produce in a molding process.

It is another feature of some embodiments of this invention to use plastic as the main material for crash sensors. The flapper, hinge, and housing can be made of the same plastic material by a molding process. Alternatively, the hinges can be made of metal or another higher melting plastic and then insert molded with the plastic parts. Metal contacts can be inserted into the housing in the same molding process. Thus, the manufacturing is simplified and minimal additional assembly is needed.

This also permits a much tighter control over the dimensions of the clearance. Plastic materials vary in their properties from batch to batch and parts made from different cavities within a multi cavity mold also show some dimensional variation. Joining the mating parts together during the molding process, assures that the flapper and its mating housing will be formed from the same batch of plastic at the same temperature and from the same cavity which has been carefully tested to yield a pair of parts with the required clearance.

Although the preferred application of the sensors described and illustrated in this disclosure is for sensing frontal impacts, the thin flat shape of these sensors makes them applicable for certain side impact sensing applications as described in copending patent application ______________ filed on even date. Similarly, the low manufacturing cost and testable features makes some of the sensors described herein applicable for passenger compartment safing and discriminating applications as disclosed in copending patent application ______________________ also filed on even date.

Although several preferred embodiments are illustrated and described above, there are possible combinations using other geometries, materials and different dimensions of the components that can perform the same function. Therefore, this invention is not limited to the above embodiments and should be determined by the following claims.

CLAIMS

We claim:

1. A frontal impact crash sensor comprising:

(a) a housing, said housing having a thickness in the sensing direction no more than half its height and width;

(b) a mass within said housing adapted to move relative to said housing in response to accelerations of said housing;

(c) means responsive to the motion of said mass to initiate an occupant protection apparatus.

2. The invention in accordance with claim 1, wherein said responsive means comprises a first and a second contact means.

3. The invention in accordance with claim 1, wherein said first contact is adapted to bias said mass toward a first position in said housing.

4. The invention in accordance with claim 1, wherein said mass and said housing are made of plastic.

5. The invention in accordance with claim 4, wherein said mass is attached to said housing by a hinge.

6. The invention in accordance with claim 5, wherein said hinge is made of plastic.

7. The invention in accordance with claim 4, wherein the interior of said housing is sealed.

8. The invention in accordance with claim 1, wherein said sensor is installed within twelve inches of the front of the vehicle.

9. The invention in accordance with claim 1, wherein said sensor is mounted such that as the mounting structure collapses the sensor maintains an orientation pointed substantially forward for the period of time until the sensor triggers.

10. The invention in accordance with claim 9, wherein said mounting structure utilizes at least 2 tabs.

11. The invention in accordance with claim 1 wherein the motion of said sensing mass is damped.

12. The invention in accordance with claim 11, wherein said damping involves the inertial gas flow through a restriction.

13. The invention in accordance with claim 11, wherein said damping involves the viscous gas flow through a restriction.

14. The invention in accordance with claim 3, wherein said bias provided by said first contact has an average magnitude of 5 to 15 G's between the travel of said mass from a first resting position to a second actuating position.

15. A frontal-impact sensor comprising:

(a) a housing;

(b) a sensing mass within said housing and rotatably supported by said housing and having a thickness less than its width;

(b) means of biasing said sensing mass toward a first position;

(c) means of closing an electrical circuit as said sensing mass moves to a second position;

whereby said sensor responds to a designed velocity change function in a frontal impact crash.

16. The invention in accordance with claim 15, wherein said sensor has a width, or height larger than its thickness.

17. The invention in accordance with claim 15, wherein the motion of said sensing mass is affected by a damping force.

18. The invention in accordance with claim 17, wherein said damping force is proportional to the velocity of said sensing mass.

19. The invention in accordance with claim 17, wherein said damping force is proportional to the square of the velocity of said sensing mass.

20. The invention in accordance with claim 15, wherein said biasing has an average magnitude of 5 to 15 G's as said sensing mass moves from said first position to said second position.

21. The invention in accordance with claim 15, wherein said sensor is installed within 12 inches of the front of the vehicle.

22. the invention in accordance with claim 15 wherein said support comprises a hinge.

23. the invention in accordance with claim 15 wherein said support comprises a knife edge and groove.

24. the invention in accordance with claim 15 wherein said support comprises a curved surface on said mass and a cylindrical surface on said housing.

25. The invention in accordance with claim 1 wherein the sensor is testable.

26. The invention in accordance with claim 1 wherein said mass has a substantially rectangular cross section.

27. The invention in accordance with claim 1 wherein said mass has a substantially circular cross section.

28. A crash sensor adapted for mounting on a vehicle comprising:

(a) a housing;

(b) a substantially planar mass in said housing;

(c) means of biasing said mass toward a first position in said housing;

(d) means of closing an electrical circuit when said mass moves to a second position in said housing.

29. The invention according to claim 28 wherein the motion of said mass is damped.

30. The invention according to claim 28 wherein said mass is rotatably connected to said housing.

31. The invention in accordance with claim 28, wherein said planer mass is a component, of which the thickness is much smaller than the width or the height.

32. The invention in accordance with claim 28, wherein said mass is connected with said housing by at least one hinge.

33. The invention in accordance with claim 32, wherein said mass, said housing, and said hinge are made of plastic and formed in a molding process.

34. The invention in accordance with claim 32, wherein said hinge is made of metal and molded into said housing.

35. The invention in accordance with claim 34, wherein said hinge provides a biasing force.

36. The invention in accordance with claim 28, wherein said mass is semi-circular.

37. The invention in accordance with claim 36, wherein said mass is attached to said housing at least partially along its diameter.

38. The invention in accordance with claim 28, wherein said mass is rectangular.

39. The invention in accordance with claim 38, wherein said mass is attached to said housing at least partially along one of its edges.

40. The invention in accordance with claim 28, wherein said housing is profiled to match said mass shape so that the clearance between said mass and said housing restricts gas flow to provide said damping.

41. The invention in accordance with claim 28, wherein said housing is tailored to maintain a substantially constant clearance between said mass and said housing

throughout the moving range of said mass.

42. The invention in accordance with claim 28, wherein said means of biasing comprises a spring.

43. The invention in accordance with claim 28, wherein said means of biasing comprises a magnet.

44. The invention in accordance with claim 28, wherein said first and second contacts are combined with said housing in a molding process.

45. The invention in accordance with claim 28, wherein said first contact provides a biasing force for said mass.

46. The invention in accordance with claim 42, wherein said contacts are treated to become adhesive to plastic so as to prevent separation between said contacts and said housing within the operating temperature range of said sensor.

47. The invention in accordance with claim 44, wherein said treatment provides hermetical sealing to said sensor.

48. A sensing device, comprising:

(a) an interior mechanism, needed to be isolated from the ambient environment;

(b) conductive connectors, extended from said interior mechanism to the outside of said device;

(c) a plastic body, through which said connectors pass;

(d) means of bonding said plastic body and said connectors by a metal-plastic adhesive material to prevent separation caused by temperature variations; whereby said sensing device is hermetically sealed.

49. The invention in accordance with claim 48, wherein said connectors are inserted and assembled with said plastic body in a molding process.

50. A method of manufacturing a crash sensor with the following steps:

(a) Bend the metallic parts of said sensor into desired shapes;

(b) Treat the surfaces of said metallic parts on the portion where it is to be coupled with the plastic part of said sensor;

(c) Form said sensor in a molding process with said conductors in appropriate positions to be combined with said plastic parts of said sensor into a single piece;

(d) Seal said sensor.

51. A method of attaching the conductors of a crash sensor to the plastic parts of said sensor comprising:

(a) Form said conductors of said sensor into desired shapes;

(b) Means of treating the surfaces of said conductors on the portion where it is to be coupled with said plastic parts of said sensor;

(c) Means of Inserting and molding said conductors into said plastic parts; whereby said conductors and said plastic parts remain attached throughout the operating temperature range of said sensor.

52. A crash sensor adapted for mounting in the passenger compartment of a vehicle, comprising:

(a) a housing;

(b) a sensing mass, arranged to move in said housing;

(c) means of closing an electrical circuit when said mass moves from a first position to a second position in said housing.

(d) means of using inertial flow to dampen the motion of said sensing mass throughout the motion of said mass from said first position to said second position;

(e) means of biasing said mass toward said first position in said housing;

53. A side impact crash sensor comprising:

(a) a housing;

(b) a mass within said housing adapted to move relative to said housing in response to accelerations of said housing;

(c) means responsive to the motion of said mass to initiate an occupant protection apparatus.

54. The invention in accordance with claim 53, wherein said responsive means comprises a first and a second contact means.

55. The invention in accordance with claim 53, wherein said first contact is adapted to bias said mass toward a first position in said housing.

56. The invention in accordance with claim 53, wherein said mass and said housing are made of plastic.

57. The invention in accordance with claim 56, wherein said mass is attached to said housing by a hinge.

58. The invention in accordance with claim 5, wherein said hinge is made of plastic.

59. The invention in accordance with claim 56, wherein the interior of said housing is sealed.

60. The invention in accordance with claim 53, wherein said sensor is installed on the side door structure of a vehicle.

61. The invention in accordance with claim 53, wherein said crash sensor is installed inside the side skin of a vehicle.

62. The invention in accordance with claim 53 wherein said sensor has a thickness in the sensing direction which is smaller that its width or height.

63. The invention in accordance with claim 53, wherein the sensing of said motion of said mass involves the use of an electronic circuit.

64. The invention in accordance with claim 53 wherein the motion of said sensing mass is damped.

65. The invention in accordance with claim 64, wherein said damping involves the inertial gas flow through a restriction.

66. The invention in accordance with claim 64, wherein said damping involves the viscous gas flow through a restriction.

67. The invention in accordance with claim 55, wherein said bias provided by said first contact has an average magnitude of 5 to 15 G's between the travel of said mass from a first resting position to a second actuating position.

68. A side-impact sensor comprising:

(a) a sensing mass;

(b) means of biasing said sensing mass toward a first position;

(c) means of closing an electrical circuit as said sensing mass moves to a second position;

(d) means to mount said sensor on the side of a vehicle;

whereby said sensor responds to a designed velocity change function in a side impact crash.

69. The invention in accordance with claim 68, wherein said sensor has a width, or height larger than its thickness.

70. The invention in accordance with claim 68, wherein the motion of said sensing mass is affected by a damping force.

71. The invention in accordance with claim 70, wherein said damping force is proportional to the velocity of said sensing mass.

72. The invention in accordance with claim 70, wherein said damping force is proportional to the square of the velocity of said sensing mass.

73. The invention in accordance with claim 68, wherein said biasing has an average magnitude of 5 to 15 G's as said sensing mass moves from said first position to said second position.

74. The invention in accordance with claim 68, wherein said sensor is installed on the side door structure of a vehicle.

75. The invention in accordance with claim 68, wherein said sensor is installed inside the side skin of a vehicle.

76. A side impact safing sensor comprising:

(a) a switch comprising a first member and a second member;

(b) means of mounting said switch on the side structure of a vehicle;

(c) means of forcing said first member to contact said second member, and causing said switch to change its conductive state when said vehicle is impacted in a side crash.

77. A side impact sensor system comprising:

(a) at least one discriminating sensor containing as acceleration sensing mass, and

(b) at least one safing sensor comprising a switch responsive to a force from a side impact.

78. The invention in accordance with claim 68 wherein said sensor requires a larger velocity change to trigger for short pulses than for longer ones.

79. The invention in accordance with claim 53 wherein the sensor is testable.

80. The invention in accordance with claim 53 wherein said mass has a substantially rectangular cross section.

81. The invention in accordance with claim 53 wherein said mass has a substantially circular cross section.

82. A side impact sensor system comprising at least two discriminating sensors located on one side of the vehicle.

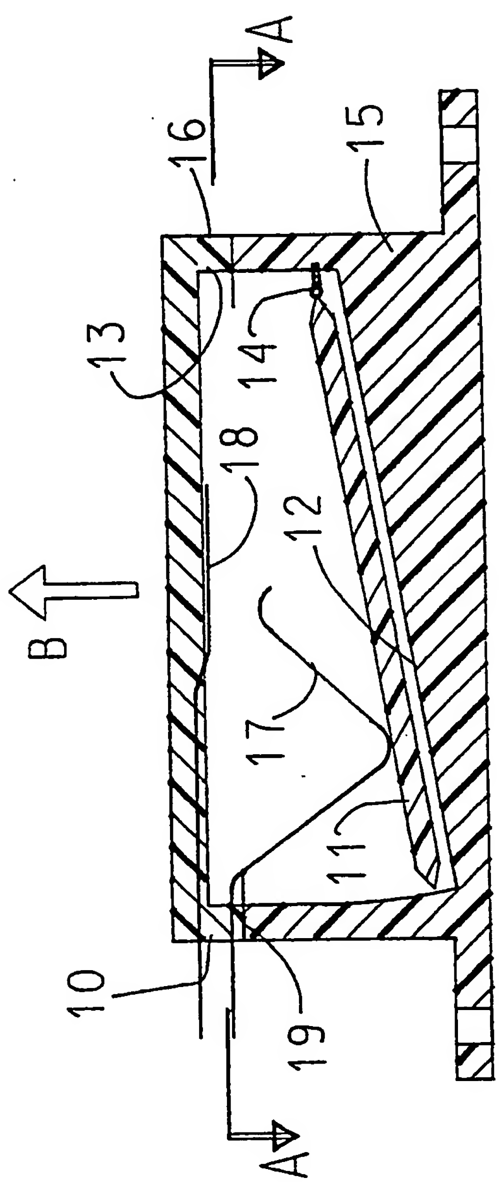

FIG. 1

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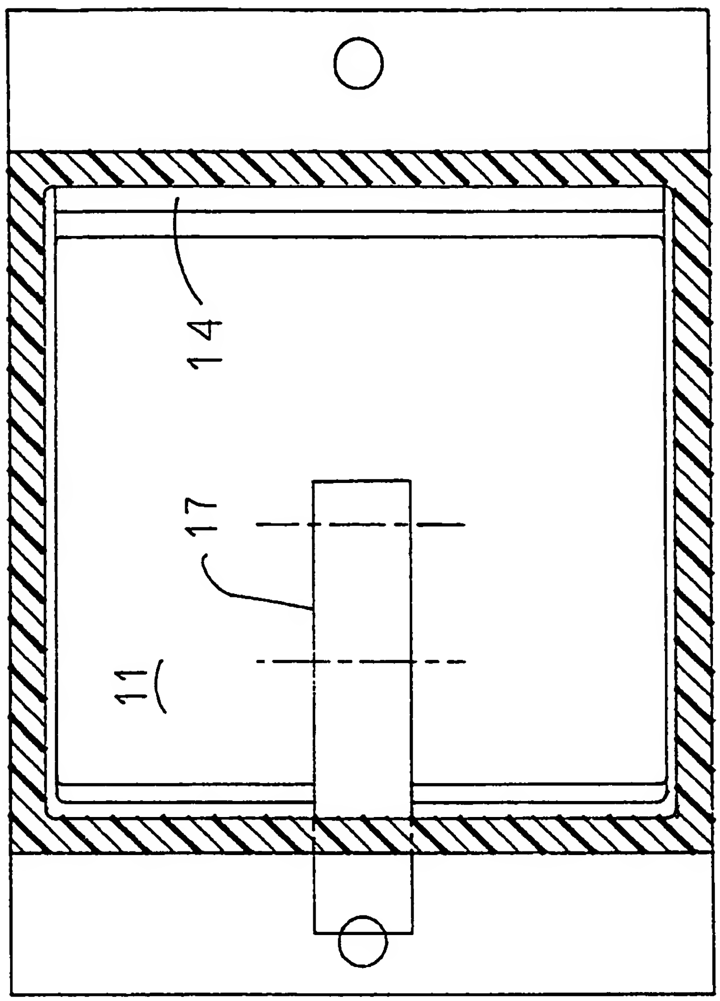

FIG. 2

SUBSTITUTE SHEET

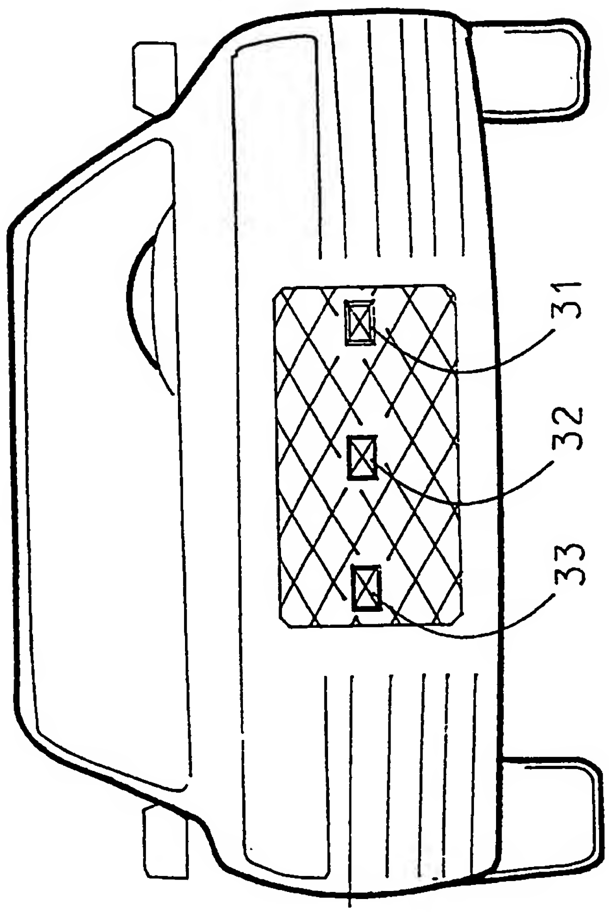

FIG. 3

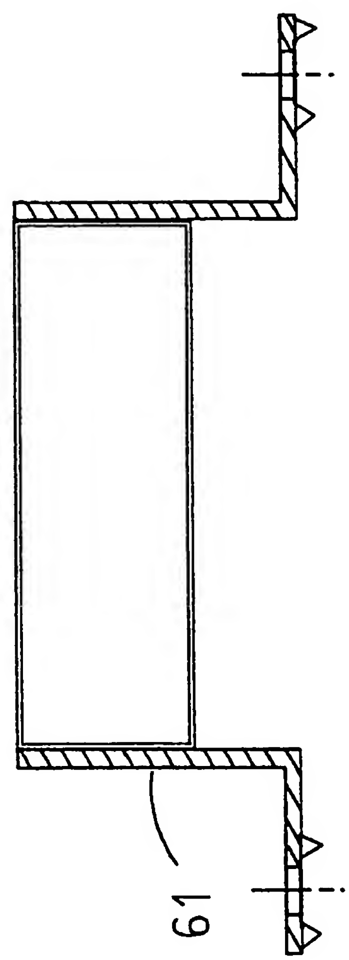

FIG. 4

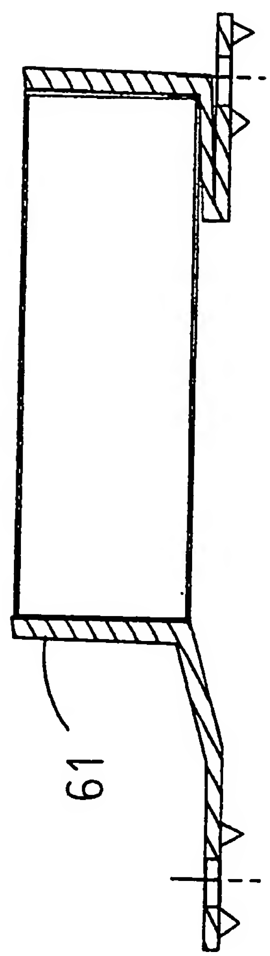

FIG. 4A

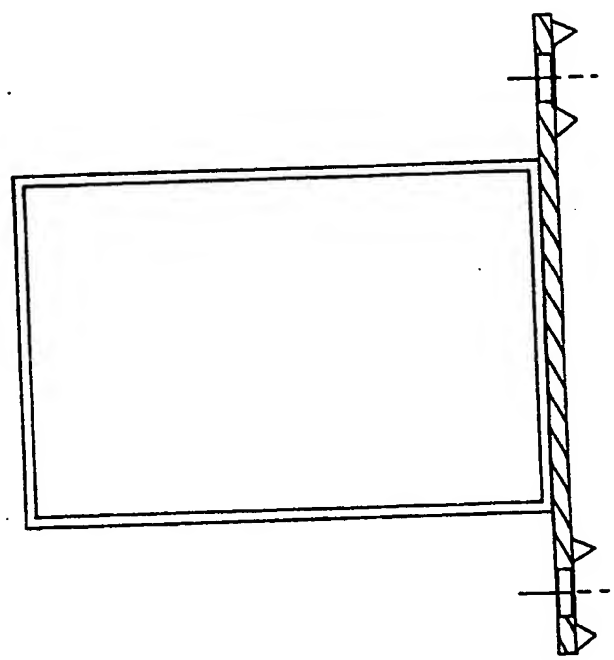

FIG. 5

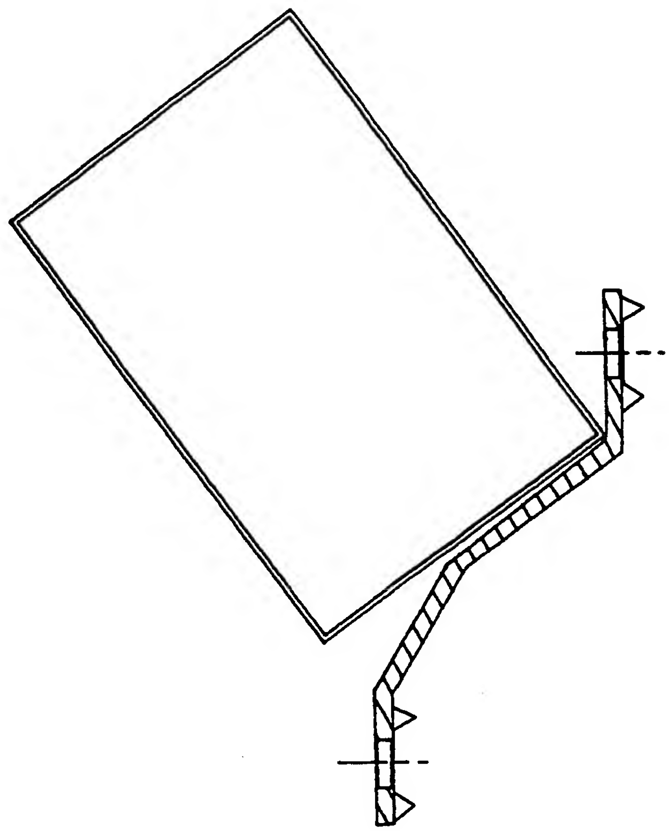

FIG. 5A

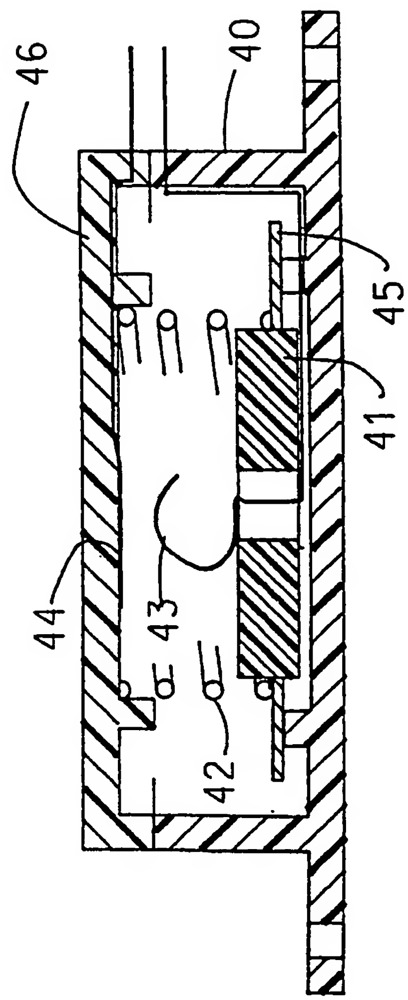

FIG. 6

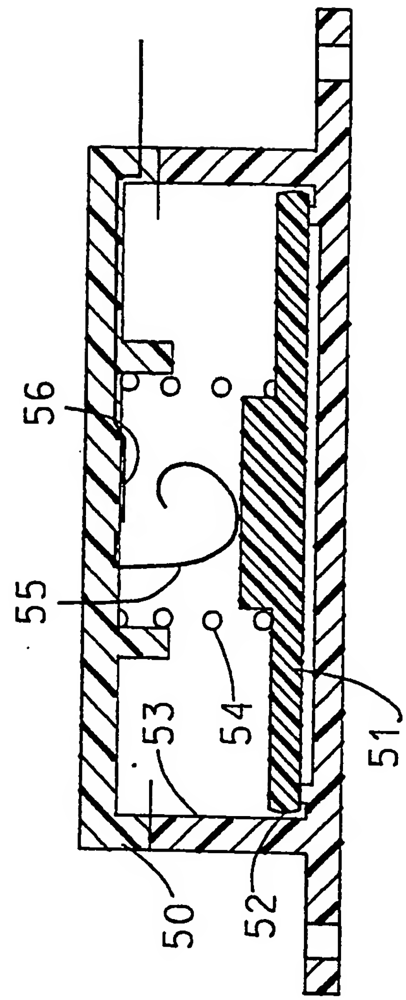

FIG. 7

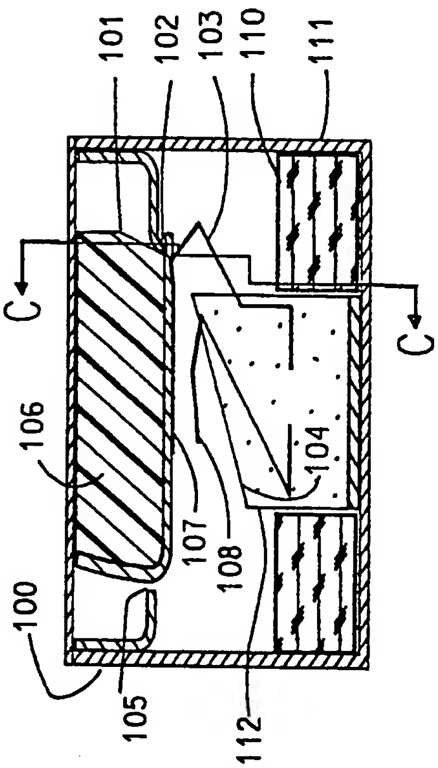

FIG. 8

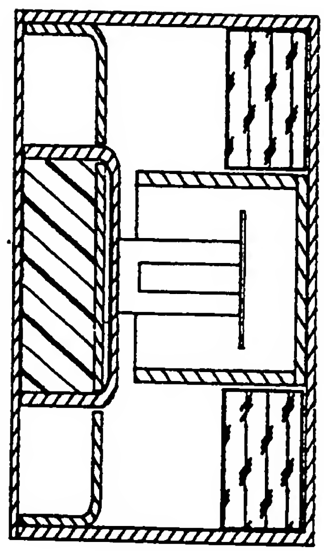

FIG. 9

12/27

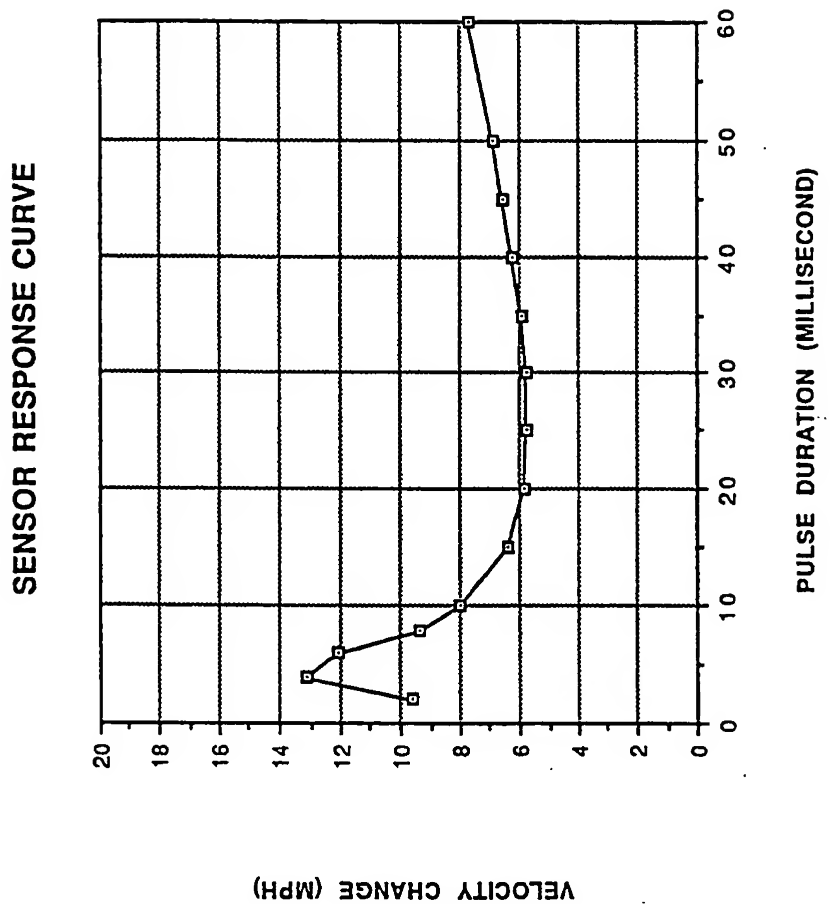
SENSOR RESPONSE CURVE
VELOCITY CHANGE (MPH)
0
2
4
6
8
10
12
14
16
18
20
PULSE DURATION (MILLISECOND)
0
10
20
30
40
50
60

FIG. 10

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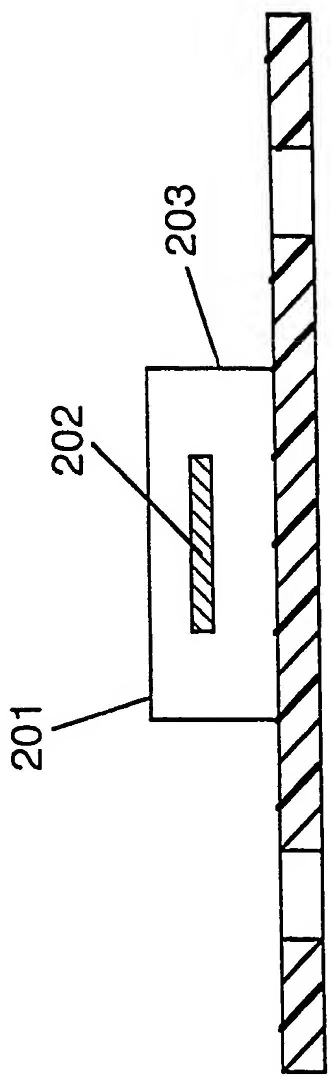

FIG. 11

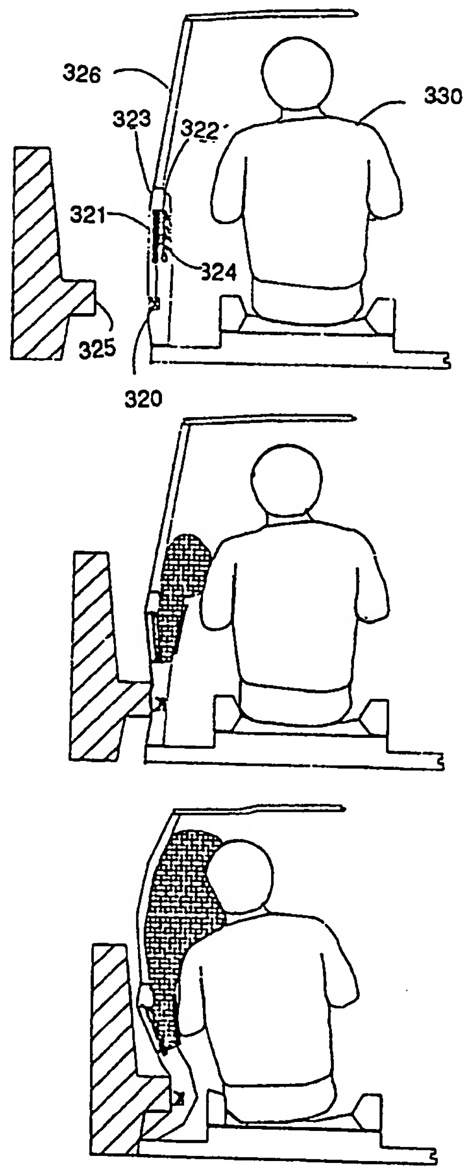

FIG. 12

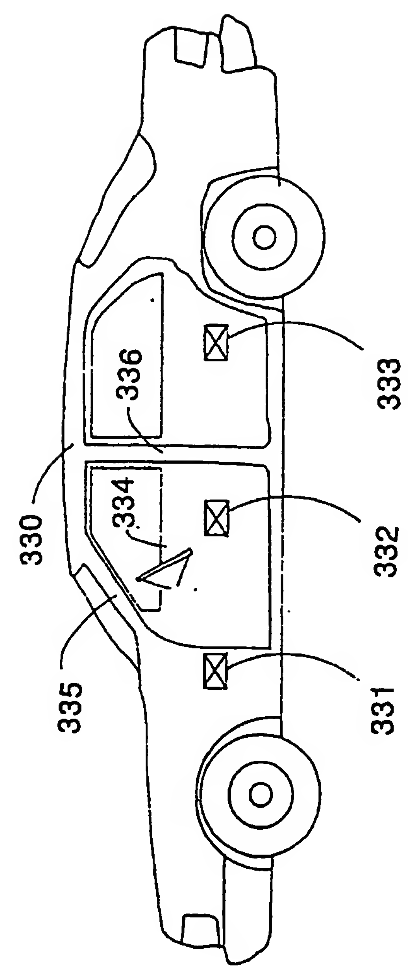

FIG. 13

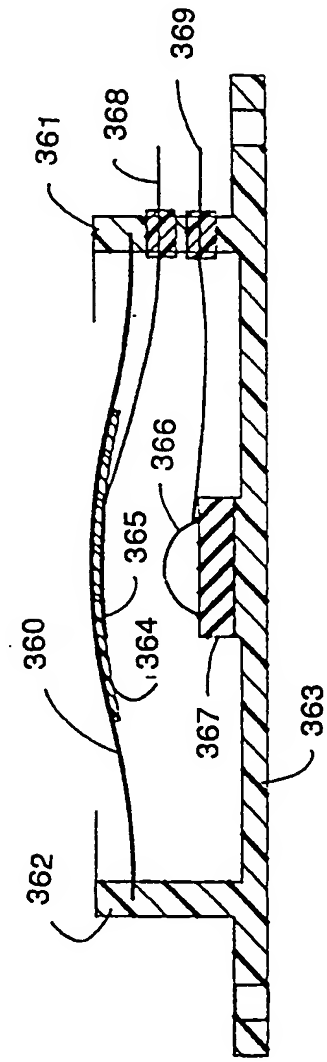

FIG. 14

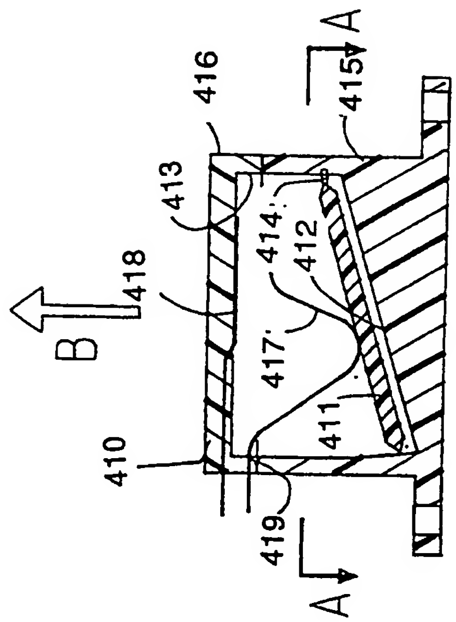

FIG. 15

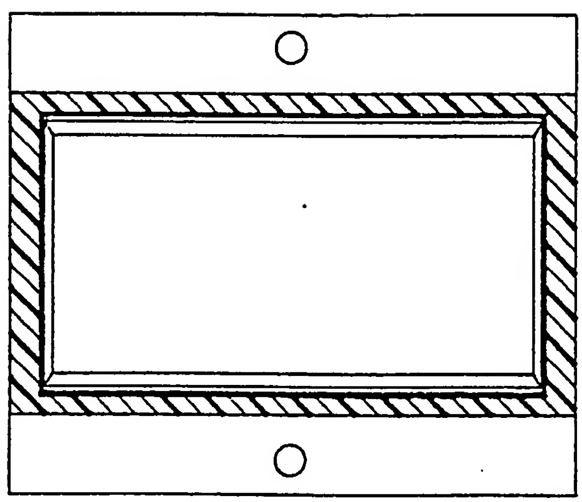

FIG. 16

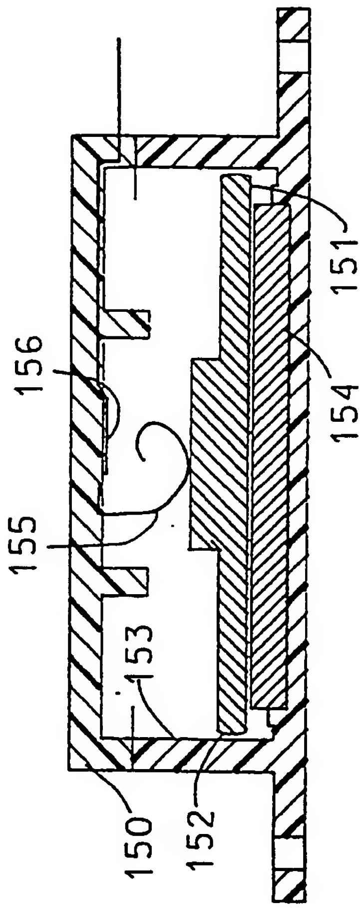

FIG. 17

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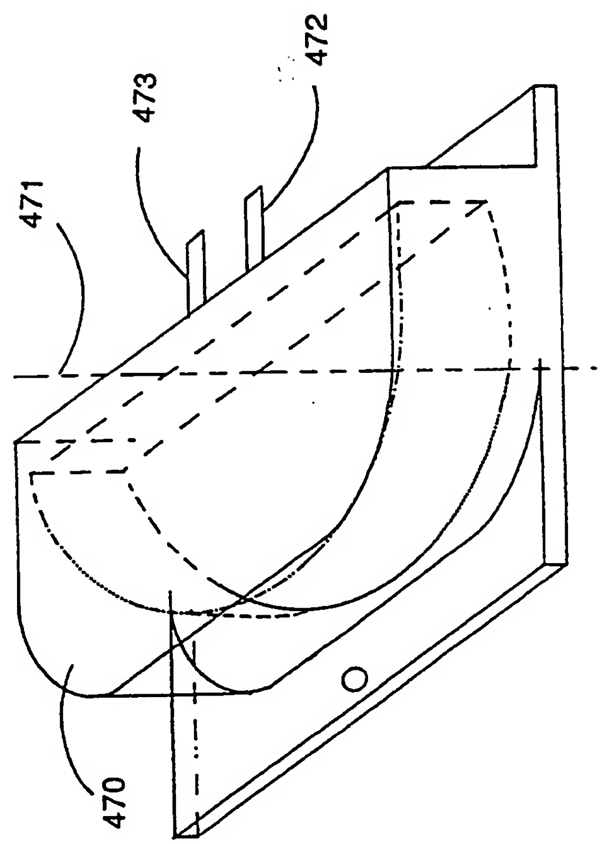

FIG. 18

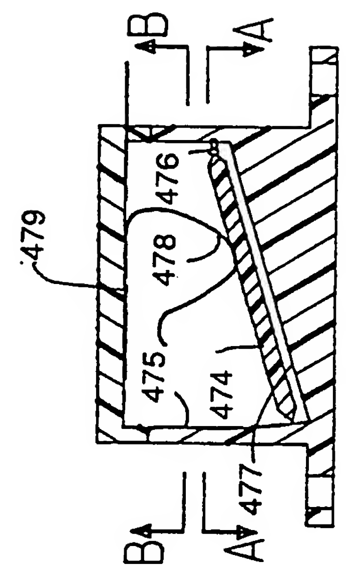

FIG. 19

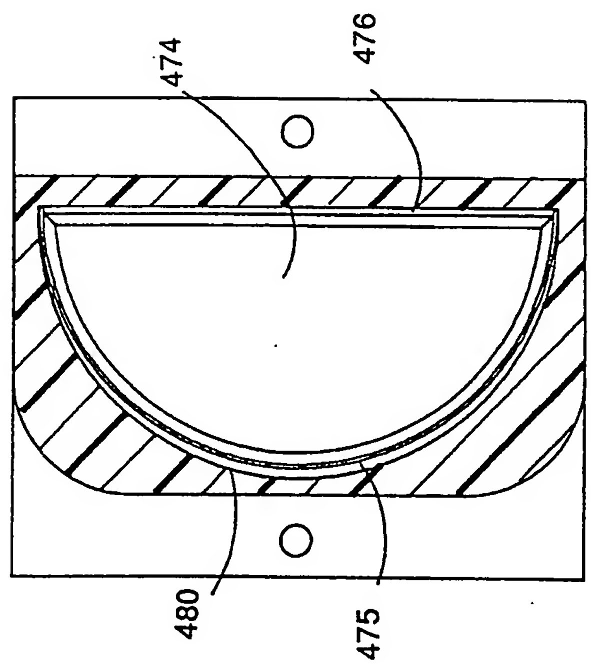

FIG. 20

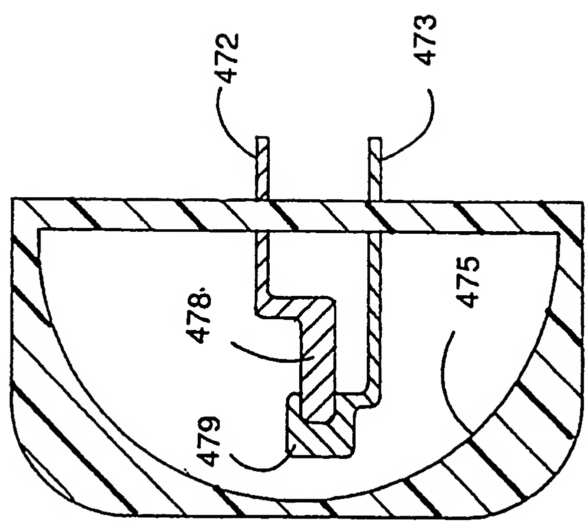

FIG. 21

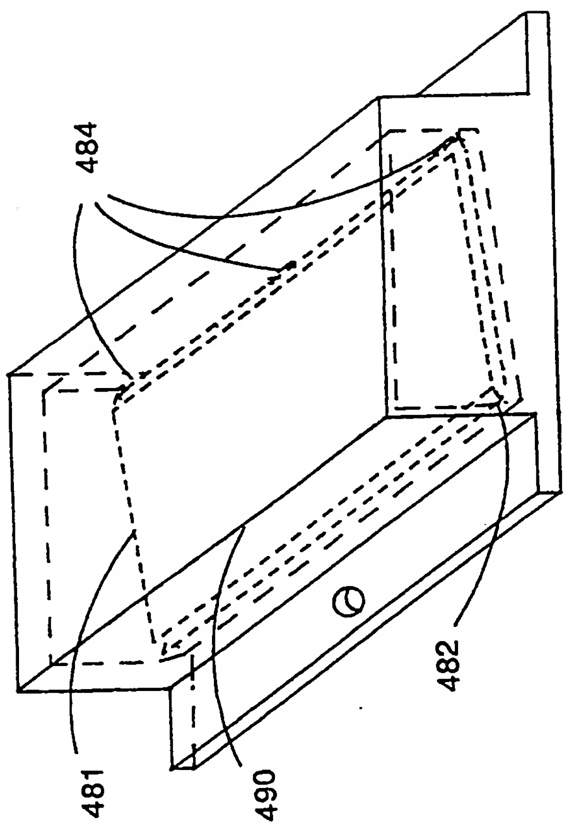

FIG. 22

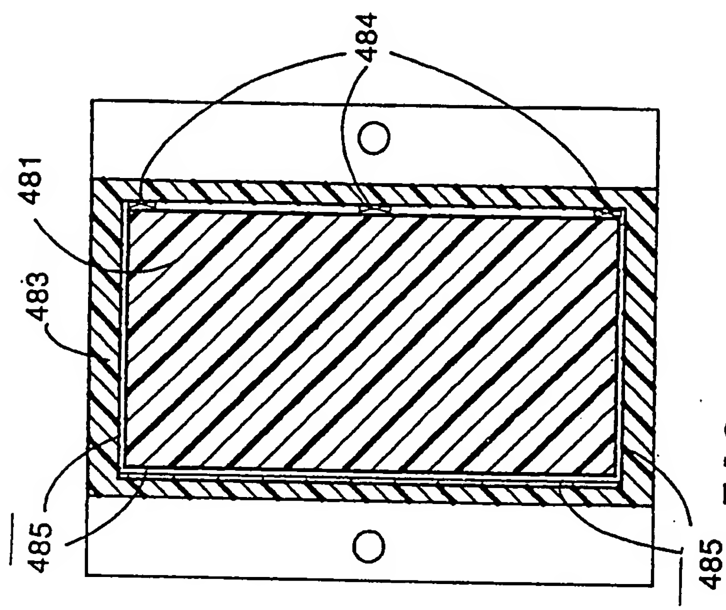

FIG. 23

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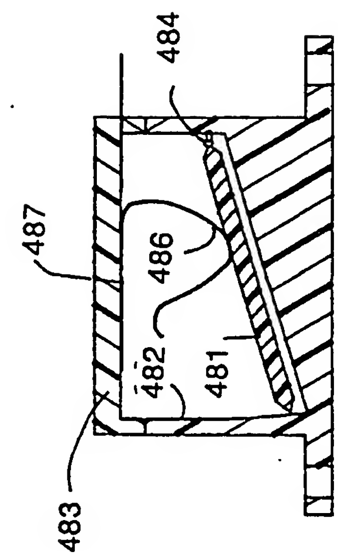

FIG. 24

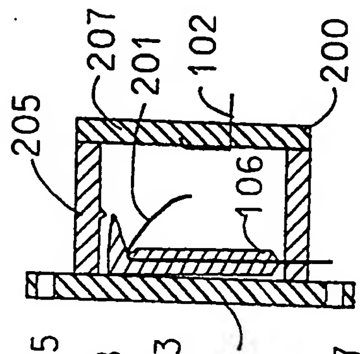

FIG. 25c

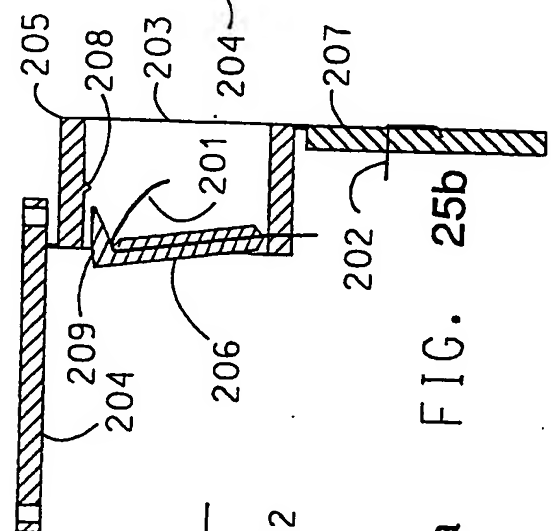

FIG. 25b

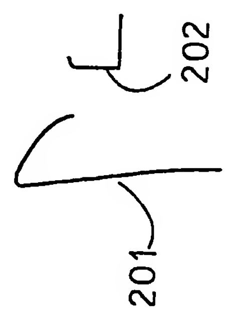

FIG. 25a

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US90/01017

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5) H01H 35/14
U.S CL. 200/61.45R, 61.45M, 61.48, 61.51

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S. CL.	180/282 200/61.45R, 61.45M, 61.48, 61.49, 61.61-51.53 280/731, 735

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No [13]
X,Y	US, A, 4,028,516 (HIRASHIMA ET AL) 07 June 1977, See entire document	1-4,8-11,15-19,21-39,41-46,53-55,60-62,64,68-72,74-76,79-81
X,Y	US, A, 4,249,046 (LIVERS ET AL) 03 February 1981, See entire document	1,15,28,52-55 60,61,64,68-72, 74-76, 78-81
X,Y	US, A, 4,262,177 (PAXTON ET AL) 14 April 1981, See entire document	1-3,15-19, 21-23, 25-38, 41, 42,44-47 52-55,60-62, 64,68-72, 74-81, 82
Y	US, A, 4,190,879 (TISSOT) 26 February 1980 See entire document	62

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
21 MAY 1990	17 JUL 1990
International Searching Authority	**Signature of Authorized Officer**
ISA/US	Veronica ... for J. R. SCOTT

Form PCT/ISA/210 (second sheet) (Rev.11-87)

CL6/6/90

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
Y	US, A, 4,329,549 (BREED) 11 May 1982 Note column 5, lines 1-51, reference to 5Gs and the damping force being proportional to the sensing mass velocity.	14,18,19,20 67,70-73
X,Y P	US, A, 4,816,627 (JANOTIK) 28 March 1989 See entire document	1-3,8,11-13, 15-19,25-27, 28-31,36,40, 41,43-45,47 52-54,65,66, 68-71,74-76, 79,81
X,Y	US, A, 3,974,350 (BREED) 10 August 1979 See entire document	1,2,15,28,52, 53,54,68,76
X,Y	US, A, 2,369,977 (O'TOOLE) 20 February 1945 Note column 2, lines 2-7 which state that the inertia switch casing may be mounted to any suitable location of a vehicle	1,8,21,25,28, 30,53,60-62, 68,74,75,76 79
X,Y	US, A, 4,362,913 (KUMITA ET AL) 07 December 1982 See entire document. Note hinged mass 6, 6a, 6b	1,2,4-9,11 15-19,22,25, 27,28-33,41, 42,44,47,52-54,56-62,64, 68,70,72,74-76,79,81
X,Y	US, A, 4,321,438 (EMENEGGER) 23 March 1982 See entire document. Note hinged mass 12, 52	1,4-6,15,22 28,31,53,54, 56,57,60,61, 68,74,75,79

International Application No PCT/US90/01017

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

P	US, A, 4,902,861 (COOK) 20 February 1990 See entire document	1-3,7-13,21,25-28,39,40,44,45 47,52-54,60-62, 68-72,74-76, 79-81
P	US, A, 4,900,880 (BREED) 13 February 1990 See entire document	14,20,67,73

V ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers ______ because they relate to subject matter [12] not required to be searched by this Authority, namely:

2.☐ Claim numbers ______, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

3.☐ Claim numbers ______, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.